

EPAct/V2/E-89: Assessing the Effect of Five Gasoline Properties on Exhaust Emissions from Light-Duty Vehicles Certified to Tier 2 Standards

Final Report on Program Design and Data Collection

Appendix K Detailed Measurement and Analysis Methods

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Office of Transportation and Air Quality
U.S. Environmental Protection Agency

National Renewable Energy Laboratory
U.S. Department of Energy

Coordinating Research Council

NOTICE

This technical report does not necessarily represent final EPA decisions or positions. It is intended to present technical analysis of issues using data that are currently available. The purpose in the release of such reports is to facilitate the exchange of technical information and to inform the public of technical developments.

A. QA OBJECTIVES FOR TESTING OF LIGHT-DUTY VEHICLES

The QA objectives for precision, accuracy, and completeness are presented in Table 1. All measurements will be representative of the fuels, vehicle engine exhaust, and conditions being measured. Completeness equals number of tests performed divided by number of tests proposed times 100.

TABLE 1. PRECISION, ACCURACY, AND COMPLETENESS OBJECTIVES FOR LIGHT-DUTY ENGINES

Measurement <u>Parameter (Method)</u>	<u>Reference</u>	Experimental <u>Conditions</u>	Precision		
			<u>Std. Dev.</u>	<u>Accuracy,%</u>	<u>Completeness,%</u>
HC (FID)	SwRI and SAE ^{a,b}	Dilute Exhaust	0.04 ^a	±15 ^b	>95
CO (NDIR)	SwRI and SAE ^{a,b}	Dilute Exhaust	0.06 ^b	±20 ^b	>95
CO ₂ (NDIR)	SwRI and SAE ^{a,b}	Dilute Exhaust	4 ^b	±5 ^b	>95
NO _x (CL)	SwRI and SAE ^{a,b}	Dilute Exhaust	0.08 ^a	±10 ^b	>95
Particulate, 47 mm (Gravimetric)	SwRI and SAE ^{a,b}	Dilute Exhaust	0.05 ^a	±10 ^b	>95
Fuel Economy (Carbon Balance)	SwRI and SAE ^{a,b}	Dilute Exhaust	1 ^a	±5 ^b	>95
Aldehydes (DNPH/HPLC)	EPA ^(1,2) CRC ⁽³⁾	Dilute Exhaust	See Appendix K		>95
Alcohols (water impinger/GC-FID)	EPA ^(1,2) CRC ⁽³⁾	Dilute Exhaust	See Appendix K		>95

^a Precision experienced at SwRI, but precision is vehicle dependent.

^b Accuracy goals were based on SwRI experience and SAE Technical Paper 790232, "Identification, Quantification and Reduction of Sources of Variability in Vehicle Emissions and Fuel Economy Measurements," N.J. Sheth and T.I. Rice, 1979.

^c ±100% of defined detection limit; precision generally improves with increased sample concentration.

B. SAMPLING METHODS

The sampling system is comprised primarily of the exhaust sampling system to which continuous measurement devices, a dilute exhaust bag sampler, impinger and cartridge samplers, and particle filters are attached. The sampling procedures employed for the determination of regulated and unregulated emissions for light-duty engines are identified below. In the event of errors, mishaps, or deviations from procedure, the project leader, Kevin Whitney is to be notified.

All procedures will be designed to maximize test-to-test repeatability. For example, the following steps will be taken:

- The position and angle of the vehicle cooling fan shall be consistent for each vehicle and each test.
- The airflow around the vehicle during tests shall be kept consistent.
- To the extent possible, the CARB laboratory correlation program will be used in support of this program's QA procedures.
- Sample side verification of exhaust analyzers will be performed monthly by sampling span gases from a sample bag.
- Sample flow proportionality will be verified after each emissions test. For PM samples, a proportionality statistic will be calculated. For other parameters, the constancy of tunnel flows will be verified.
- Duplicate vehicle coastdown checks from 70 to 30 mph will be performed following each sulfur purge procedure.
- A check will be performed before, during, and at the end of each test to assure that manually controlled parameters are set and adhered to during each test.
- Battery chargers will be utilized to maintain the state of battery charge of test vehicles between vehicle prep procedures and emissions tests.
- The LA92 driving cycle will be used for the vehicle prep procedures to match the driving cycle used in emissions tests.
- NOx analyzers will be equipped with NH3 traps to prevent contamination of NOx converters.

B.1. Exhaust Gas Sampling System Description

A Horiba selectable flow CVS system will be used to sample exhaust emissions. Test technicians first connect the vehicle exhaust pipe to the CVS inlet. While the vehicle operates on the dynamometer, an adjustable-speed turbine blower dilutes the exhaust with ambient air. This dilution prevents the exhaust moisture from condensing and provides controllable sampling conditions. A sample pump and a control system transfers diluted exhaust aliquots to several different Kynar bags during specific phases of each test run. Regulating needle valves maintain constant sample flow rates for the alcohol impingers and DNPH cartridges, and mass flow controllers maintain proper flow into the bags. Exhaust backpressure will be recorded continuously at the tailpipe during emissions testing. Table 2 summarizes the CVS system specifications.

TABLE 2. CVS SPECIFICATIONS

Measurement Variable	Operating Range Expected in Field	Instrument Description	Range	Accuracy	How Verified / Determined
Pressure	950 to 1050 millibar	Horiba Variable-Flow Constant Volume Sampler	0 to 1500 millibar	± 2 % reading	Sensors calibrated and verified during installation.
Temperature	20 to 45 °C		0 to 100 °C	± 2 % reading	
Volumetric Flow Rate	200 to 500 ft ³ /min		150 to 1100 ft ³ /min	± 0.5 % reading	

B.2. Dilute Exhaust Bag Sampling

The Kynar bags (sample and background) specified for HC speciation analysis will be removed from the Horiba sampling system, marked with a sample ID/custody label, and transported to the GC laboratory. Analysis of sample Bag 1 will begin immediately (within one hour) for the C₁-C₄ analysis and within four hours for the benzene-toluene and C₅-C₁₂ analysis. Times that analyses are started will be reported. For tests in which multiple test phases will be analyzed for HC speciation, analysis order shall be: Bag 1, Bag 3, Bag 2, Background Bags.

B.3. Carbonyl Compound Sampling

Heated (235 ±15°F) sample lines from the dilution tunnel carry sample gas to a cart which holds the DNPH sampling cartridges. The cart includes controls for the flow rate and measures the volume sampled. Thermocouples with electronic readouts allow recording of the gas temperature sampled, so coupled with the recorded barometric pressure, the volume sampled can be corrected to standard temperature and pressure.

Immediately following the end of the sampled test phase (within 15 minutes), the DNPH cartridge will be extracted with 5.0 ml acetonitrile in accordance with the manufacturer’s instructions. The extract will be promptly sealed and analyzed (within one hour), or stored at <40°F for no longer than three calendar days until analysis. Every effort will be made to analyze the sample the same day. Samples and sampling media will be stored separately from calibration standards.

B.4. Alcohol Sampling

Heated (235 ±15°F) sample lines from the dilution tunnel carry sample gas to a cart which holds glass impingers filled with ultra-pure water. The cart includes controls for the flow rate and measures the volume sampled. Thermocouples with electronic readouts allow recording of gas temperature sampled, so coupled with the recorded barometric pressure, the volume sampled can be corrected to standard temperature and pressure. The impingers are maintained in an ice bath during sampling.

Immediately following the end of the sampled test phase, the impinger contents will be carefully transferred to sealed containers and stored at <40°F for no longer than six calendar days until analysis. Every effort will be made to analyze the samples on the same day as collection. Samples and sampling media will be stored separately from calibration standards.

Ethanol recovery will be checked during every blank test conducted in this program. Recovery shall be ≥ 92 percent.

B.5. Filter Sampling and Weighing

Whatman Teflo filters with polypropylene support rings will be used for particulate matter (PM) measurements. Particle filters are stored, conditioned, and weighed in a room at SwRI that strictly conforms to 40 CFR 86.1312 and Part 1065. A PM filter field blank will be tested daily. This field blank shall be a tared filter that is installed in a sample holder, then returned to the filter room for weighing by the same procedures as actual samples.

C. SAMPLE HANDLING AND CUSTODY

Only PM filters, bag, impinger, and cartridge samples involve manual handling, because gaseous emission measurements are made and recorded by the computer-controlled data system associated with the continuous sampling system.

C.1. Particle Filters

Particle filters are managed by a bar code tracking system. Test I.D., date, time, and technician name are tracked with this system. This procedure is compliant with 40 CFR 86.1312 and Part 1065.

C.2. Bag Samples

Because bag samples may be handled by multiple analysts, a bag sample tag is affixed to each sample or background bag. With this tag, progress and times of analysis can be recorded. A bag sample tag is shown in Figure 1.

BAG ANALYSIS		
S A M P L E		
Project No. 13363.01.101 EPA Work Assignment 0-1		
Test No.:	Date: / /	
Dyno 8	Operator:	
Bag Description		
LA-92 Unified Cycle		
<input type="checkbox"/> Bag 1 End of Test: _____ : _____ <input type="checkbox"/> Bag 2 End of Test: _____ : _____ <input type="checkbox"/> Bag 3 End of Test: _____ : _____		
Analysis Required	Analysis Start (Time)	Analyzed by:
<input type="checkbox"/> C ₁ -C ₄ speciation	:	
<input type="checkbox"/> Benz-Tol speciation	:	
<input type="checkbox"/> C ₅ -C ₁₂ speciation	:	

FIGURE 1. BAG SAMPLE TAG

C.3. Cartridge and Impinger Samples

Sampling of carbonyl compounds is to be performed with DNPH cartridges, and alcohols, with liquid impingers, as described above. Tracking of sample times and extraction times will be made by recording times on the cartridge tag (Figure 2) and impinger data sheet (Figure 3).

ALDEHYDE DNPH CARTRIDGE		
Project No. 13363.01.101 EPA Work Assignment 0-1		
Test No.:	Date: / /	
Dyno 8	Analyst:	
Bag Description		
LA-92 Unified Cycle		
<input type="checkbox"/> Bag 1	End of Test: _____ :	_____
<input type="checkbox"/> Bag 2	End of Test: _____ :	_____
<input type="checkbox"/> Bag 3	End of Test: _____ :	_____
Cartridge Extraction Required within 15 min	Extraction (Time)	Analyst Initials:
<input type="checkbox"/> Bag 1	:	
<input type="checkbox"/> Bag 2	:	
<input type="checkbox"/> Bag 3	:	
<input type="checkbox"/> Background	:	

FIGURE 2. DNPH CARTRIDGE TAG

Project 13363.01.101		Date: / /		Dyno 8	
Initials:					
Test Number:	DNPB Cartridge		Alcohol Impinger		
	Sample	Background	Sample	Background	
Test Cycle:	Temp:	Temp:	Temp:	Temp:	
Barameter, "Hg:	Counts:	Counts:	Counts:	Counts:	
End Time:	Sx 1°	Sx 2°	Sx 1°	Sx 2°	
Test Cycle:	Temp:	Temp:	Temp:	Temp:	
Barameter, "Hg:	Counts:	Counts:	Counts:	Counts:	
End Time:	Sx 1°	Sx 2°	Sx 1°	Sx 2°	
Test Cycle:	Temp:	Temp:	Temp:	Temp:	
Barameter, "Hg:	Counts:	Counts:	Counts:	Counts:	
End Time:	Sx 1°	Sx 2°	Sx 1°	Sx 2°	

FIGURE 3. IMPINGER AND CARTRIDGE SAMPLING DATA SHEET

D. ANALYTICAL METHODS

The analytical procedures employed for the determination of regulated and unregulated emissions for light-duty engines are given below. In the event of errors, mishaps, or deviations from procedure, the project leader, Kevin Whitney is to be notified.

D.1. Filter Weighing

The chamber in which the PM filters are conditioned and weighed conforms to 40 CFR 86.1339 and Part 1065 without deviation.

D.2. Gaseous Analyzers

Horiba analytical benches equipped with either MEXA 7000-Series analyzers are used to determine NMHC, CO, NO_x, and CO₂ concentrations in dilute exhaust. Sample pumps transfer the dilute exhaust from Kynar bags to each analyzer as commanded by the control system. Each analyzer used for these measurements is accurate to ±2 percent. Table 3 provides a summary of the emissions analyzers to be used.

TABLE 3. EMISSION ANALYZER SPECIFICATIONS

Measurement Variable	Expected Operating Range	Instrument Mfg., Model / Type	Instrument Range(s)	Accuracy ^a	How Verified / Determined
THC	0 - 100 ppmC	Horiba FIA-220 or FIA-726LE / FID	0 - 10 ppmC 0 - 50 ppmC 0 - 1000 ppmC	± 1.0 % FS or ± 2.0 % of the calibration point ^a	Gas divider with protocol calibration gases at 11 points (minimum) spaced throughout span (including zero)
NO _x	0 - 100 ppm	Horiba CLA-220 or CLA-750LE / CL	0 - 30 ppm 0 - 100 ppm 0 - 300 ppm		
Low CO	0 - 50 ppm	Horiba AIA-210 or AIA-721LE / NDIR	0 - 10 ppm 0 - 50 ppm		
CO	0 - 1000 ppm	Horiba AIA-220 or AIA-721A / NDIR	0 - 1000 ppm		
CO ₂	0 - 1.5 %	Horiba AIA-220 or AIA-722 / NDIR	0 - 4 %		

^aThe most stringent accuracy specification applies for each calibration point.

E. QUALITY CONTROL

SwRI verifies performance of each analyzer through a series of zero and calibration gas challenges. Each zero and calibration gas must conform to certain specifications and/or be NIST-traceable. Table 4 summarizes the applicable QA/QC checks. If all calibration gases and QA/QC checks meet their specifications, then SwRI will infer that the emissions analyzers meet Table 1 accuracy specifications.

SwRI verifies all new Standard Reference Material (SRM) or other NIST-traceable reference gas concentrations with an emissions analyzer that has been calibrated within the last 30 days. The operator will first zero the analyzer with a certified zero grade gas and then span it with a NIST SRM (or equivalent) three times to ensure stability and minimal analyzer drift.

The operator will then introduce the new reference gas into the analyzer and record the concentration, followed by reintroduction of the NIST SRM to ensure that the analyzer span point does not drift more than ±0.1 percent of span point. The operator will repeat these last two steps until three consistent values are obtained. The mean of these three determinations must be within one percent of its NIST SRM concentration. SwRI will then consider the reference gas as suitable for emissions analyzer calibrations.

For chemical evaluations, QC measures are generally specified in the analytical method. A summary of actions taken to ensure data quality for analytical procedures is presented in Table 5.

TABLE 4. EMISSION ANALYZER QA/QC CHECKS

QA/QC Check	When Performed / Frequency	Expected or Allowable Result	Response to Check Failure or Out of Control Condition
NIST-traceable calibration gas verifications	Prior to being put into service	Average of three readings must be within $\pm 1\%$ of verified NIST SRM concentration	Identify cause of any problem and correct; discard bottle and replace if necessary
Zero-gas verification against NIST certified zero gases	Prior to being put into service	HC < 1 ppmC CO < 1 ppm CO ₂ < 400 ppm NO _x < 0.1 ppm O ₂ between 18 and 21%	Discard bottle and replace
Gas divider linearity verification	Monthly	All points within $\pm 2\%$ of linear fit FS within $\pm 0.5\%$ of known value	Identify cause of any problem and correct; replace gas divider if necessary
Analyzer calibrations	Monthly	All values within $\pm 2\%$ of point or $\pm 1\%$ of FS; Zero point within $\pm 0.2\%$ of FS	Identify cause of any problem and correct; recalibrate analyzer
Wet CO ₂ interference check	Monthly	CO 0 to 300 ppm, interference ≤ 3 ppm CO > 300 ppm, interference $\leq 1\%$ FS	
NO _x analyzer interference check	Monthly	CO ₂ interference $\leq 3\%$	
NO _x analyzer water quench check	Once, before each phase of program	Proper operation	
NO _x analyzer converter efficiency check	Monthly	NO _x converter efficiency > 95%	

TABLE 5. SUMMARY OF QA/QC CHECKS FOR ANALYTICAL PROCEDURES

Procedure	Type	Blank	Field Blank	Duplicate Analysis	Continuing Calibration Check	Holding Time	Preservation During Storage
Light Alcohols	GC-FID	1 per batch	1 per day	1 per 10 samples	1 per 10 samples	6 days	Keep at <4°F
Aldehydes and Ketones	HPLC-UV	1 per batch	1 per day	1 per 10 samples	1 per 10 samples	15 minutes to extraction; 3 days	Keep at <4°F
HC Speciation	GC-FID	1 per day	n/a	no	end of day	1 hour for C2-C4 Analysis	protect from UV light
Particulate Matter Mass	Gravimetric	Reference filter every 2 hours	n/a	At least three measurements on each filter	Monthly reference check	Filters may be out of chamber only ≤ 1 hr	Temperature and humidity control

F. INSTRUMENT/EQUIPMENT TESTING, INSPECTION, AND MAINTENANCE

Gaseous analyzers conform to 40 CFR 86.1311 without deviation. Internal QC checks and corrective actions are summarized in Table 6.

TABLE 6. INTERNAL QUALITY CONTROL CHECKS AND CORRECTIVE ACTION

EQUIPMENT AND/OR MEASUREMENT	OPERATIONAL CHECK	CONTROL LIMIT(S) (reference no.)	CORRECTIVE ACTION
Driver's aid	Speed agreement ^a	EPA ⁽²⁹⁾	Repair and/or recalibrate
CVS	Propane recovery ^b	$\pm 2\%$ ^(25,29)	Check for leaks and by procedural assessment
	Speed, RPM ^a	$\pm 5\%$ ^(25,29)	Check speed sensor and recalibrate rpm
Engine Dynamometer	Load and Speed, RPM ^a	Federal Register ⁽²⁵⁾	Check and/or repair load cell and rpm indicator; recalibrate
CO bag analyzer	CaSO ₄ and ascarite conditioning column	Blue indicator of CaSO ₄ ^(25,29)	Change CaSO ₄ and ascarite column soon after CaSO ₄ indicator turns color. Leak-check before continuing bag analysis.
NO _x bag analyzer	Percent efficiency of NO ₂ to NO converter ^b	Percent efficiency greater than 90% ^(25,29)	Repair analyzer
Sampling bags	Leak-check bags before and after each test	Bag holds gauge vacuum pressure of 27.6 in. Hg	Discard bag and note finding in test results. Repeat test as applicable.
HFID analyzer	Leak-check sampling system ^a	Flowmeter float is at zero position	Correct leak before sample analysis
	Sample gas temperature immediately before heated filter and before the HFID ^a	$375 \pm 10^\circ\text{F}$ ^(25,29)	Locate sampling line heating problem and correct before conducting sample analysis
	Zero and span before each range ^c	Zero at 0.0 of full- scale and span to set value ^(25,29)	Determine problem and adjust zero and span accordingly
	Pre-analysis and post-analysis zero and span of each range ^c	Zero and span drift- limit of 2% of full- scale chart deflection ^(25,29)	Repeat test
	Pre-analysis and post-analysis tunnel HC backgrounds ^c	Continuous tunnel and bag HC backgrounds agree to within 1% of full-scale chart deflection ^(25,29)	Determine cause for discrepancy and correct

TABLE 6. INTERNAL QUALITY CONTROL CHECKS AND CORRECTIVE ACTION

EQUIPMENT AND/OR MEASUREMENT	OPERATIONAL CHECK	CONTROL LIMIT(S) (reference no.)	CORRECTIVE ACTION
47 mm filter sampling system	Leak-check sampling system ^a	Flowmeter float is at zero position	Correct leak before particulate sampling
	Sampling rate ^c	Flowrate constant $\pm 5\%$ throughout test	Check for leaks or restrictions on sampling line and filter
47 mm reference filters	Weight tolerance ^c	$\pm 1\%$ of the nominal filter loading ⁽²⁷⁾	Reweigh all filters being conditioned
Particle Dilution Tunnel	Particle sampling zone temperature ^c	125°F or less	Increase level of sample dilution
Aldehydes and ketones	Leak-check sampling system ^c	Flowmeter float is at zero position	Correct leak before sample collection
	Sampling rate ^c	Flowrate constant $\pm 5\%$ throughout test	Check for leaks or restrictions on sampling line and filter
	Dry gas meter volume ^d	Compare to flowmeter estimate	Recalibrate or replace dry gas meter
Aldehydes and ketones	Sample identification ^c	Date, project, cycle, and test no. if designated	Correct labeling
	Sample preparation ^c	Within 15 minutes of end of sampled phase	Void sample
	Sample analysis ^c	Within 3 days of end of sampled date	Void sample
HC, CO, NO _x , and CO bag analyzers	Leak-check analyzer sampling system ^a	Flowmeter float at zero position	Correct leak before bag analysis
	Zero and span before each range ^c	Zero at 0.0 of full-scale and span to set value ^(25,29)	If not adjustable using analyzer zero and gain control within specified limits, repair analyzer
	Pre-analysis and post-analysis zero and span of each range ^c	Zero and span drift limit of 2% of full-scale meter reading ^(25,29)	Repeat bag analysis

In the event of out of specification conditions, equipment should be repaired and recalibrated. If a significant delay will result, the project leader, Kevin Whitney is to be notified.

G. INSTRUMENT/EQUIPMENT CALIBRATION AND FREQUENCY

Sampling and analytical methodologies and test procedures adhere to Title 40 CFR Parts 86 and 600 requirements. All equipment calibrations are conducted according to the schedules in 40 CFR § 86.116. Table 7 summarizes the relevant calibrations, Title 40 CFR citations, and their frequencies. Calibrations and QA/QC checks are discussed in more detail below.

TABLE 7. EQUIPMENT CALIBRATIONS SUMMARY

Equipment Description	Title 40 CFR Procedure	Calibration Frequency
CO analyzer	§ 86.121	Monthly
CO ₂ analyzer	§ 86.122	Monthly
HC analyzer	§ 86.124	Monthly
NO _x analyzer	§ 86.123	Monthly
Chassis dynamometer	§ 86.118	Daily
CVS system	§ 86.119	Weekly
Speciated Hydrocarbons	EPA ⁽⁴¹⁾	Each Sample Set
Alcohols	EPA ⁽³⁹⁾	Each Sample Set
Aldehydes and Ketones	EPA ^(1, 2, 3)	Each Sample Set

Analytical equipment in the chemistry laboratories is calibrated at least once daily, with a calibration verification performed at the end of the batch.

G.1. Gas Meter Calibrations

All gas meters, selected from the list of routinely used instruments given in the recall database, are calibrated to conform to 40 CFR 86.1320. Any necessary correction is made by mechanically adjusting the meter and recalibrating.

G.2. Gaseous Analyzers

The gaseous analyzers to be utilized in this program are discussed in the following sections.

G.2.1. Hydrocarbon Analyzers

The HC analyzers used in this testing program are calibrated in conformance with 40 CFR 86.1321.

G.2.2. Carbon Monoxide Analyzers

The CO analyzers used in this testing program are calibrated in conformance with 40 CFR 86.1322 and 40 CFR 89.320.

G.2.3. Oxides of Nitrogen Analyzers

The NO_x analyzers used in this testing program are calibrated in conformance with 40 CFR 86.1323 and 40 CFR 89.321.

G.2.4. Carbon Dioxide Analyzers

The carbon dioxide (CO₂) analyzers used in this testing program are calibrated in conformance with 40 CFR 86.1324 and 40 CFR 89.322.

G.2.5. Methane Analyzers

The methane analyzers used in this testing program are calibrated in conformance with 40 CFR 86.1325, without deviation.

G.3. Analyzer Gases

The gases used for instrument calibration conform to 40 CFR 86.114 and 40 CFR 89.312 without deviation.

SwRI verifies each new working zero air (or N₂) cylinder's impurities to ensure that it is suitable for emissions analyzer zero checks. Comparisons between a certified Vehicle Emission Zero (VEZ) Gas (or equivalent) and the candidate zero gas will serve this purpose. SwRI will employ an emissions cart (or suite of instruments) that has been calibrated within the last 30 days for this procedure. The operator will zero the analyzers with certified VEZ gas and span them with NIST-traceable reference gases to ensure stability and minimal analyzer drift. The operator will then introduce the candidate cylinder's zero gas to the sample train and record the HC, CO, CO₂, and NO_x values. The results must fall within specified ranges for the zero gas to be deemed suitable for instrumental analyzer calibrations.

Prior to the monthly exhaust emission analyzer calibrations, SwRI verifies the calibration gas divider linearity with an HC analyzer known to have a linear response and a HC span gas. The operator will first zero and then span the instrument such that the span occupies 100 meter or chart divisions. The operator will operate the divider in each of its settings in descending order and compare the observed results with a linear scale. The difference between the commanded and observed concentrations must be within ± 2.0 percent of the commanded concentration. Also, this difference must be less than ± 0.5 percent of the span value.

NIST-traceable calibration gases, in conjunction with a verified gas divider and zero gas, will create individual gas concentrations with which to challenge each instrumental analyzer. The gas divider will generate 11 concentrations in 10 percent increments from 0 to 100 percent of each analyzer's span. Analyzer response at each point must be within ± 2.0 percent of the concentration or ± 1.0 percent of span, whichever is more stringent. Zero gas response must be within ± 0.2 percent of span (the CFR requires ± 0.3 percent). If any point is outside these limits, operators will generate a new calibration curve.

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